Future Directions of BNL Nuclear and High Energy Physics

Peter Bond
Acting Associate Director
for High Energy and Nuclear Physics
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Office of Science
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BROOKHAVEN NATIONAL LABORATORY
BROOKHAVEN SCIENCE ASSOCIATES

Background

- You have heard and will hear a lot of science talks this week so I will not repeat these talks here – rather I will focus on proposed future directions and projects that have come out of scientific results and discussions.

User input has been and will be key

Nuclear Physics

Priorities, Vision, Outlook

The #1 priority for Nuclear Physics at BNL, present and future,

is *RHIC*

- RHIC has been and is running spectacularly both for HI and for polarized p (thanks to DOE and Renaissance Technologies)

Near term

Exploit the scientific opportunities at RHIC

- Enormous gains in knowledge will continue to be made (in A+A and Spin) with near term upgrades and incremental improvements
  - Luminosity, polarization, DAQ, particle ID, η coverage
- Optimized operations
  - Running time vs. investment (for efficiency and the future)
- Research support
  - Experimental – Research & ops support, detector R&D
  - Theory support – including thermodynamics on the lattice

RHIC Upgrade Science

QCD at High T and ρ	Is there a QCD Phase Transition to QGP; what are its properties? Thermalization: How do we evolve from a low-entropy initial state to a maximal entropy state on short time scales? Deconfinement: Do the degrees of freedom in the initial state have deconfined color charges? Chiral Symmetry: Is chiral symmetry restored at high T and r?
QCD at High E, Low x	What is the nature of gluonic matter in strongly interacting particles? Is this gluonic matter a CGC and is it the source of QGP? Is the low-x structure of nucleons in nuclei different from that of free nucleons?
QCD & Hadron Structure	How do gluons contribute to the proton spin? What are the u, d, s quark & antiquark polarizations in the proton? What orbital angular momentum is carried by the partons in a proton? What role does transverse spin play in QCD?

Mid term plan

- RHIC II
  - EBIS to increase the range of ion species available and improve operations efficiency
  - e-cooling to be constructed to increase the HI luminosity by a factor of 10
  - Detector upgrades to take advantage of these capabilities
  - Science case for RHIC II has been made in working group white papers led by user community

  - Plan small BNL participation in LHC ATLAS HI program

Mid-Term Strategy: 2006 - 2011

Phased implementation of key upgrades for PHENIX and STAR detectors including help from non-DOE funding and collaborative resources results in

Two large detectors well equipped for RHIC II physics

Study the new form of matter with resolving power afforded by hard probes

Annual data runs during this period will exploit these upgrades for critical advances in the Heavy Ion and Spin physics programs—

At the same time continued improvements in machine performance proceed

RHIC II luminosity upgrade *(electron-cooling of ion beams)* proceeds along technically-driven schedule

Longer Term

Evolve RHIC into "QCD Laboratory"

- Address the compelling questions in QCD revealed by the discoveries at RHIC
  - Involve the RHI, Spin and DIS communities and in articulating the future science of RHIC and eRHIC

- R&D/investments → the tools and techniques needed to address the scientific questions

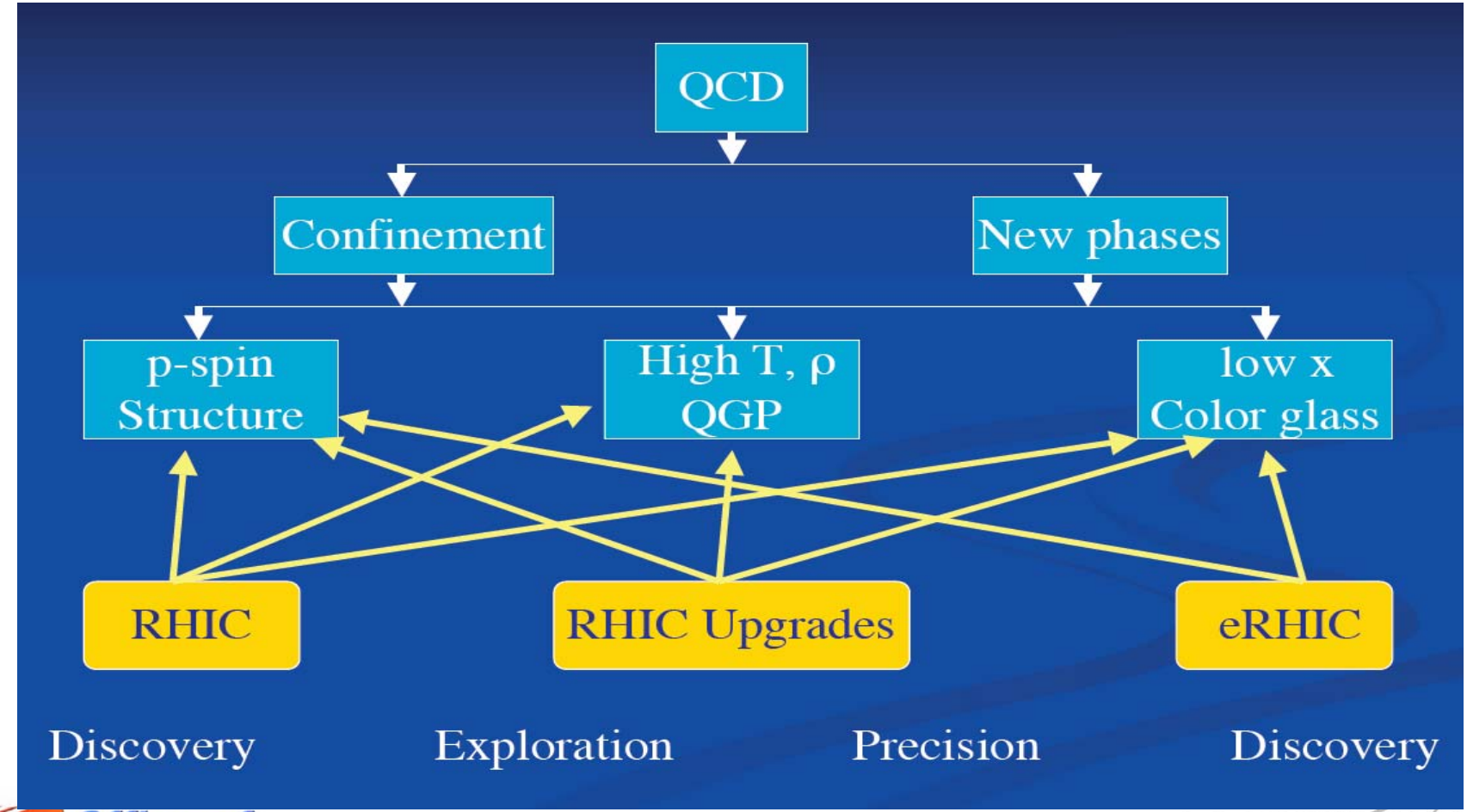
What is QCDLab ?

- e-cooling is implemented, detectors are upgraded
- A 10GeV electron injector is added to RHIC
- Computing power (e.g. BlueGene–L) is added to allow more powerful theory calculations

- The result – $A-A, A-B, \vec{p}-\vec{p}, e-A, \vec{e}-\vec{p}$ all possible

a phenomenal facility for study of QCD

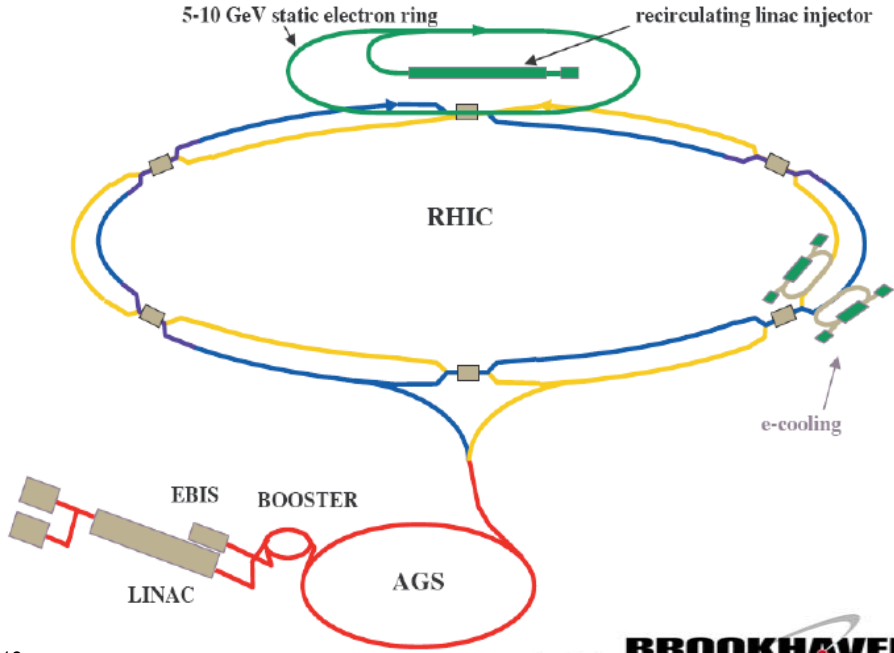
QCD Laboratory



RHIC → RHIC II/eRHIC (QCDLab)

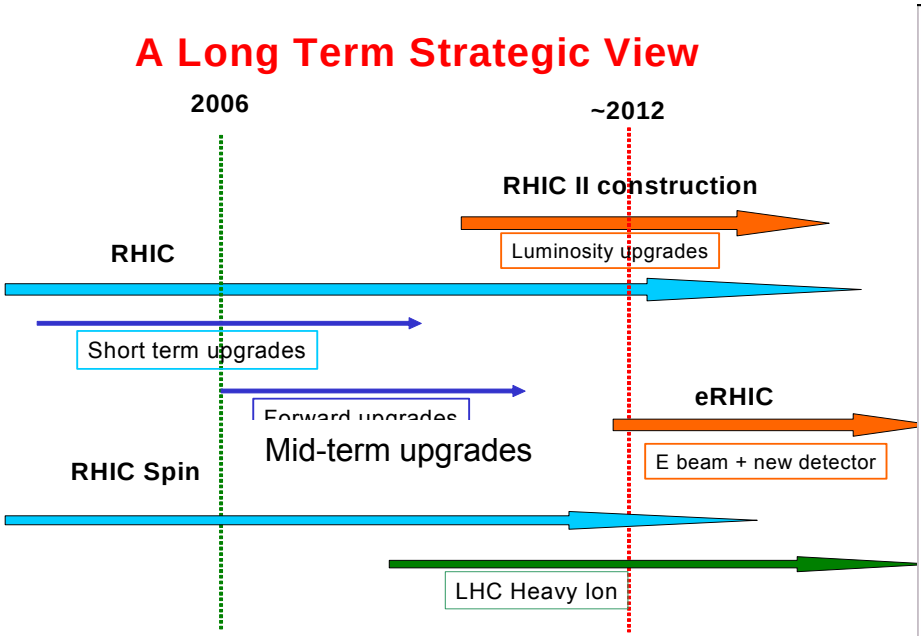
- RHIC II
  - An additional order of magnitude in average luminosity (beyond near term incremental increases)
  - Detector enhancements
- eRHIC
  - Electron ring or linac
  - New detector

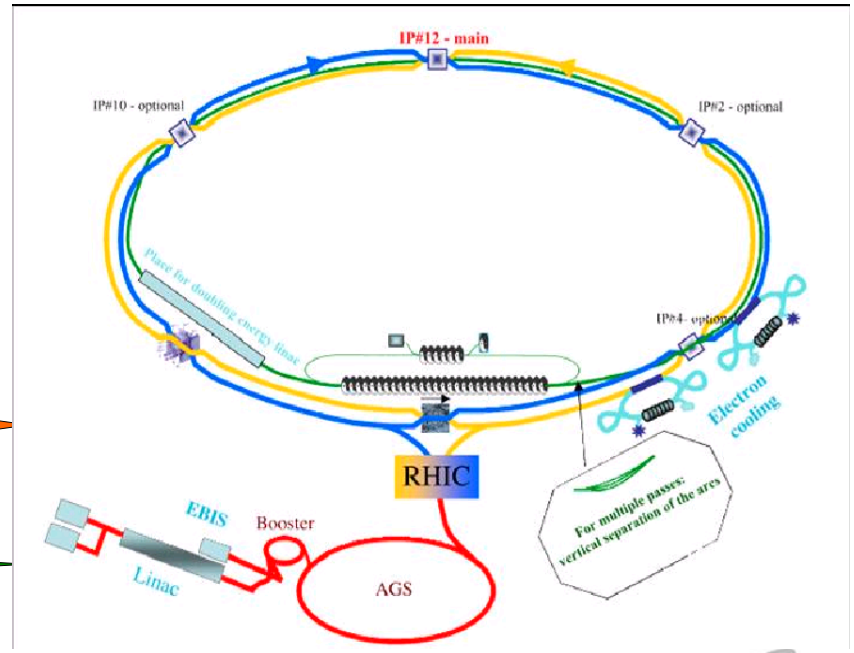
Critical technologies (principally electron cooling) enable both RHIC II and eRHIC Higher integrated luminosity through longer luminosity lifetime



RHIC Science Outlook

- QCD at high temperature and density: QGP ... sQGP
- QCD at high energy and low x: Physics of strong color fields
- QCD and the structure of hadrons: What is the origin of nucleon spin?





What are the hurdles to be overcome ?

- The technical and science hurdles are the “easy” ones
- Last year with the significant cut in NP funding any large facility appeared unlikely. The FY07 Presidential budget changed that outlook, but a number of challenges remain
- Issues
  - Making the HI science case once LHC begins
  - Need to collaborate with TJLAB on science case for QCDLab
  - TJLAB (12 GeV), RIA, other DOE offices for funding
  - Cost

Making QCDLab real

- First steps are meetings like the workshop July 17-22 at BNL – experts make a convincing science case to themselves
- Must then make the case to the General NP community for the 2007 Long Range Plan

And

- *Keep in mind the arguments for other audiences*
  - DOE, OMB, and Congress

  These audiences may require less detail, but need compelling reasons and each audience is vital to success

NP Summary

- RHIC's success has made BNL a world center for
  - Heavy Ion Physics
  - Spin Physics
  - Nuclear Theory (high T, high ε, high E, low x)
  - Accelerator science
- A clear (non-trivial!) path leading to a QCD Lab
  - $A+A, p+A, \vec{p}+\vec{p}, \vec{e}+\vec{p}, e+A$
  - New detector capabilities, higher luminosity and polarization

This path has ***discovery potential*** every step of the way!

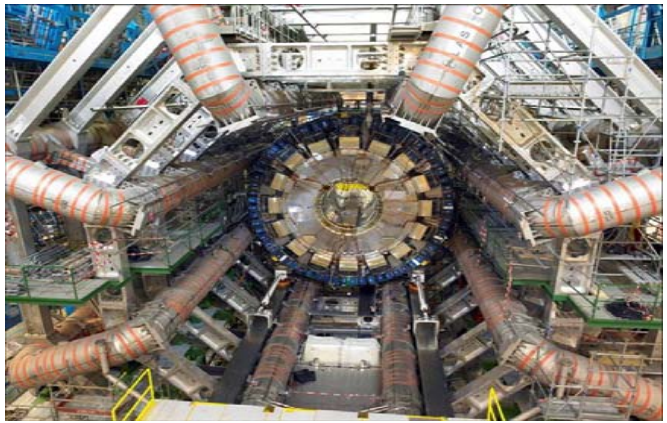
High Energy Physics

The state of HEP

- RSVP cancelled in August, 2005
  - Major planning exercise and redirection of program
- Reorganized experimental groups post-RSVP – most as user groups
  - Collider physics
    - ATLAS, D0
    - ILC Detector R&D (with Instrumentation Div.)
  - Fixed target (neutrino) & non-accelerator based physics
    - Neutrinos: MINOS, reactor θ_{13}, very long baseline
    - Cosmology, astrophysics: LSST
  - Strong theory & accelerator groups
    - High Energy Theory
    - Advanced Accelerator R&D (key to Muon Collaboration)
    - Accelerator Test Facility (HEP, BES)
    - Superconducting Magnet Division (NP, HEP, WFO)

Collider Physics - ATLAS

- Construction at LHC is completing and BNL's leading role in this has been a big success
  - Cathode Strip Chambers shipped to CERN
  - U.S. is playing a vital role under David Lissauer's leadership



- M&O: Pre-operation testing of detector components

ATLAS

- Development of Analysis Support Center at BNL
- Progress in computing software and hardware
  - Tier 1 Computing Center is building up
  - BNL computer professionals making important contributions to the ATLAS software
  - Initiation of PanDa (Production and Distributed Analysis)
- Physics Analysis
  - BNL's Analysis Support Center is up and running
    - Many tutorials, meetings and visitors in the last year
    - Helps US ATLAS community to use ATLAS software
    - Analysis "jamboree" taking place this week (30 universities)

ATLAS

- Future Plans
  - D0 effort has been decreasing and effort will gradually transition to ATLAS - planned for end of 2008
  - Analysis Support Center will continue to expand as budget permits
  - Emphasis on Tier 1 and core software
  - R&D on ATLAS upgrade
    - Work with Instrumentation Division on tracking devices which can withstand a factor of 10 greater luminosity

Collider Physics - ILC R&D

- New ILC R&D detector effort
  - Part of US ILC detector effort
    - Work on far forward ($\theta < 140$ mrad) calorimetry
    - Luminosity normalization from forward Bhabba pairs
    - Instantaneous luminosity from beamsstrahlung gammas
  - BNL role in Experiment Conceptual Design
    - Have joined massive Si detector concept study
    - Simulation and integration studies
  - Physics Dept effort coordinated with BNL Instrumentation Division

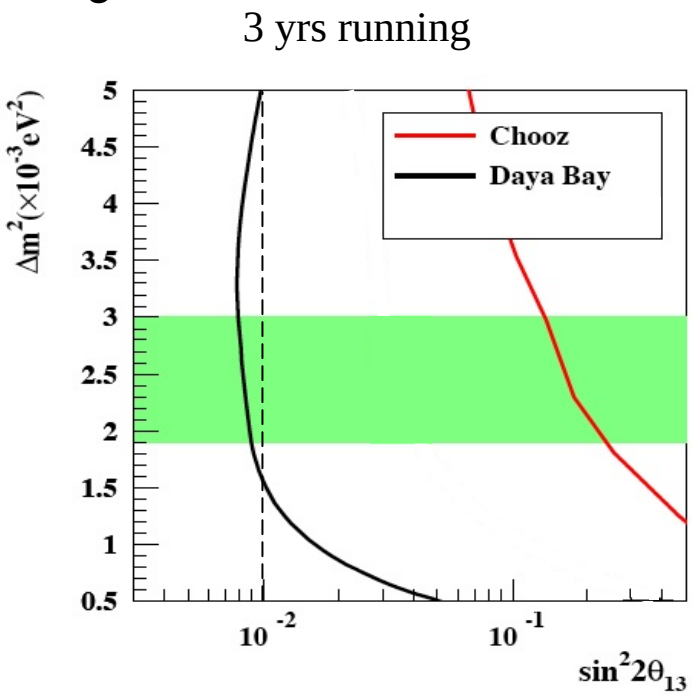
- Superconducting Magnet Division effort
  - Direct wind superconducting magnets for compact final focus

Neutrino Efforts - MINOS

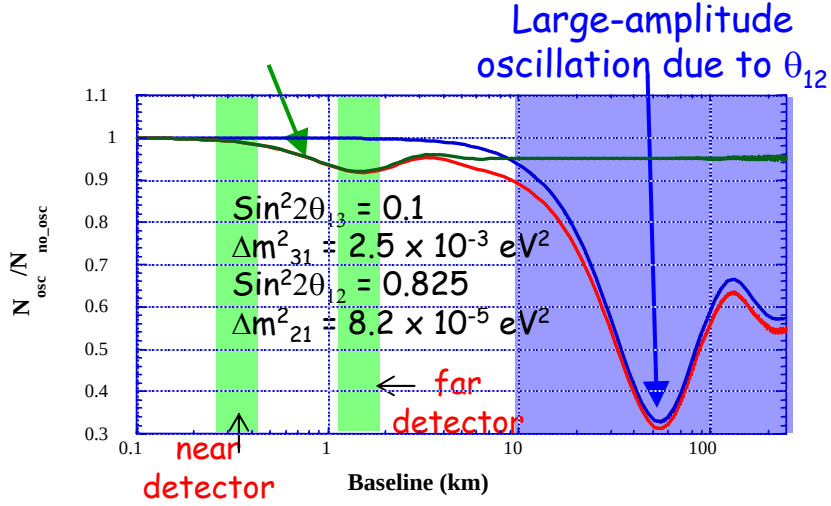
- MINOS – measure Δm^2_{23} and $\sin^2 2\Theta_{23}$
  - First result
    - $\Delta m^2_{23} = 3.05 \times 10^{-3}$ eV^2
    - $\sin^2 2\Theta_{23} = 0.88$
  - BNL leads search for ν_e appearance in far detector
  - Should finish circa 2010 (?)

Neutrino Effort – Daya Bay Reactor Experiment

- BNL has joined Daya Bay Experiment CD-0, seeking CD-1
- Precision measurement of $\sin^2 2\theta_{13}$ - the last unknown neutrino mixing angle



$$P(\bar{\nu}_e \to \bar{\nu}_e) \approx 1 - \sin^2 2\theta_{13} \sin^2\left(\frac{\Delta m^2_{31} L}{4E}\right) - \cos^4 \theta_{13} \sin^2 2\theta_{12} \sin^2\left(\frac{\Delta m^2_{21} L}{4E}\right)$$



Daya Bay Experiment to Measure θ_{13}

- BNL might provide Muon Tracker, simulations, project management
- BNL Chemistry department will provide Gd loaded liquid scintillator

Intend to begin experiment in 2010

Visit to Daya Bay (June 9-10)

- Focus on formal collaboration issues
- Developing BNL role
  - BNL has large representation on task forces which will finalize design

Very Long Baseline Neutrino Experiment

- Neutrinos from FNAL to DUSEL
  - Mass hierarcy, possible CP violation phase
  - Could use upgraded beam from Fermilab with ~1 MW
    - AGS could do it also, but….
  - Construction of large detector 2010-2017?
  - *National Effort*
    - Workshop with FNAL March 6-7, 2006
    - Start of BNL/FNAL physics study of very long baseline experiments
    - What are physics trade-offs of various detector/beam options?

Other Issues

- g-2 awaits P5 decision
  - If g-2 goes forward, BNL physicists will play important roles
- Small LSST effort formed
  - 1 core FTE + 1 FTE funded by lab
  - Work on camera sensors for LSST with Instrumentation
  - Requires strategic hire of experimental astrophysicist and build up of engineering effort for success

HEP Summary

- Reorganization of experimental program into three major efforts (theory in all) following RSVP cancellation
  - Collider physics: ATLAS/D0/ILC
  - Neutrinos: MINOS/Reactor/VLBνO
  - Accelerator R&D
- We are moving aggressively to implement plans
- FY07 budget allows continuation of effort at current level, but not (highly desired!) expansion of ATLAS physics effort

Conclusion

- In both NP and HEP the future for BNL is focused on national priorities.
- The exciting science for NP is concentrated around RHIC and that for HEP at other unique facilities.
- The next decade will be an exciting one for both and we all need to work to make it real